results of which we hope to submit to the Society in a subsequent communication.

I do not, of course, lay any claim to have discovered an antidote (in the true sense of the word) to cobra poison, but I think that the experiments above described prove the inertness of the platinum compound of cobra virus, and that this may be deemed a sufficient ground for making more extensive researches on this subject. Nor do I at present venture to make any practical suggestions in connexion with the above facts as to the treatment of cases of snake bite, for until we are acquainted with the physiological action of platinum compounds this would be premature. The responsibility of recommending any change in the recognized methods of treatment would be very great, and it would be worse than rashness to deal with a subject of such vital importance without having a thorough knowledge of the effects likely to be produced by our actions.

Before concluding my paper I must tender my thanks to Mr. R. H. Wilson, C.S., officiating magistrate of the 24 Pergunnas, for kindly assisting me in procuring live cobras for the extraction of the poison, and to my assistant, Balm Poolin Behary Saor, for much aid rendered during the progress of a work not always pleasant to the feelings, and always more or less dangerous in its nature.

II. "On Repulsion resulting from Radiation. Part V." By WILLIAM CROOKES, F.R.S., V.P.C.S. Received December 3, 1877.

(Abstract.)

This paper commences with an experimental investigation of the amount of repulsion produced by radiation on disks of various kinds, and coated with different substances. The torsion apparatus for this purpose consists of a straw beam, suspended by a fine glass torsion fibre. At one end of the beam is a rod hanging downwards, and capable of taking six experimental disks in a vertical row. The other end of the beam is furnished with a pan and adjustible weights, to balance the varying weights of the disks submitted to radiation. A standard candle, at a fixed distance from the disks, supplies the radiation, and the amount of movement under its influence is measured by a ray of light reflected from a mirror on the beam to a graduated scale. An appropriate arrangement of screens enables any selected disk to be experimented on without the others being affected, and a standard lampblacked disk being always present, the results are capable of intercomparison. The beam, torsion fibre, disks &c., are sealed up in glass, and the whole apparatus is attached to a mercury pump, capable of carrying the exhaustion to any desired point.

The experimental powders are mostly chemical precipitates, laid on the surface of mica or pith disks as a water paint, no cement being used to promote adhesion. In other cases the substances are punched, cut, or filed into the shape of disks, 17·25 millims. in diameter.

The exhaustion, which has to be effected after each change of the experimental disks, is carefully brought to the same degree both by actual measurement on a McLeod gauge, and by getting the same repulsion on the standard black disk. In this way all the different results are fairly comparable one with the other. The presence of aqueous vapour must be specially guarded against by means of tubes containing phosphoric anhydride.

The effect of residual gas in tending to equalise the amount of repulsion on variously coloured surfaces is shown in an experiment with pith disks, one being lampblacked and the other retaining its natural white surface, the standard candle being at the same distance in each case. When the exhaustion is good enough to cause a fair repulsion, the ratio between the amplitude of swing (measured by the index ray) when the black is exposed and that when the white is exposed is as 100 : 55·5; at a little higher exhaustion the ratio is—

Black : White :: 100 : 42·5;

at a still better exhaustion (at which the experiments are usually tried) the ratio is—

Black : White :: 100 : 35.

The results of the quantitative examination of the repulsion resulting from radiation when falling on about 100 different substances are given in fourteen tables. Each table is in three columns, the first consisting of the names of the substances experimented on; the second the amount of repulsion observed, reduced to the standard of 100 for lampblack; the third column gives the repulsion observed when a water screen is interposed, reduced to the same standard.

Table I gives the results of the examination of black powders. Compared with lampblack = 100, these have an average value of 92·2, which becomes 99·1 by the interposition of water.

Table II contains white powders. These have an average value of 33·5, which is reduced to 8·3 behind water. The powerful absorption for the invisible heat rays which white powders exercise is somewhat remarkable. Assuming that the ultra-red rays from a candle are almost entirely cut off by a water screen, the comparatively strong action (33·5) produced by the naked flame must be mainly due to the absorption of the invisible heat rays; and when these are cut off by water the action is diminished nearly fifty times. With black powders the water only diminishes the action about eleven times.

Table III gives the red powders. Amongst these precipitated selenium is noteworthy. To the naked flame its value is 35·8, but

when a water screen is interposed the action becomes 69·5, in comparison with standard lampblack = 100. Omitting selenium, the mean action on red powders without a water screen is 32·2, and with a water screen, 24·9.

Table IV gives the brown powders. Amongst these, peroxide of thallium is remarkable as being repelled under the influence of radiation to a greater extent than any other body hitherto examined, its value being 121·7, in comparison to lampblack = 100. Brown powders behave most like black, the averages of the columns *without* and *with* a water screen being 92·7 and 94·5.

Table V gives the yellow powders. Among these anhydrous tungstic acid resembles scarlet selenium in its anomalous action, the figures being *without* water 50·8 and *with* water 72·2. The averages of the other yellow powders are 35·7 and (behind water) 13·8.

Table VI gives green powders. These show some discrepancies, which will be referred to farther on.

Table VII gives the blue powders. The action on these is of interest, as showing a much stronger proportionate action behind a water screen than with no screen, the averages being 55·8 and 65·2.

Table VIII gives the action on dyes and colouring matters of organic origin. Among these may be noticed saffranin, and a product of the decomposition of chlorophyll, which act differently to the others.

Table IX gives the action on metals prepared in different ways and coated with lampblack, mica, &c. Curious results are shown with iron and with gold, the former metal chiefly absorbing the invisible heat rays, whilst the latter metal is principally acted on by the luminous rays.

Tables X and X*a* give the results of an examination of various silver salts in their sensitive and non-sensitive state to light. The chloride, bromide, and iodide of silver, in their different states, are exposed to the standard candle after being submitted to the action of magnesium light, sunlight, and daylight. The results show how readily a change in the state of the surface is detected by an increased amount of repulsion under the influence of radiation.

Table XI gives the results of an examination of selenium disks. These are of two kinds, the vitreous and the crystalline. The latter is in the state most sensitive to *light* action. With the crystalline disk results have been obtained which seem to show that the impact of light on its surface produces a superficial disturbance there and in the adjacent gaseous molecules, which takes some time to subside. This is connected with the change in electric conducting power of crystalline selenium—a change which, when the element is transferred from light to darkness, takes some time to subside.

Table XII gives the results of the action of radiation on various substances which do not come under any of the foregoing headings,

such as pith, mica, charcoal, glass. The complicated nature of these actions is well shown in the results given by three pith disks, the first being plain white, the second lampblacked on the front, and the third lampblacked on the back. The first is repelled with a power of 17·7, the second (the standard) with a power of 100, whilst the third is not moved at all. The repulsion exerted on the white surface must be the same in each case, but the pressure of lampblack *behind* the pith causes a radiation of heat from the back surface, which produces molecular pressure just sufficient to neutralise the pressure in front.

Experiments are shown in this table with mica, both plain and roasted, and covered on one side or the other with lampblack. The results cannot well be described in abstract.

To show that physical condition has more effect in causing repulsion than chemical composition, results are given with various kinds of charcoal. It is shown that the repulsion suffered by cocoa-nut shell charcoal is much less than that by white pith, being only 11·6 against 17·7. At the same time, a radiometer made of cocoa-nut shell charcoal, lampblacked on one side, is only moderately sensitive, instead of being superior to one made of pith lampblacked on one side. The low figure shown by the charcoal is caused by its density enabling it to conduct heat from one surface to the other. Molecular pressure is, therefore, generated on both the back and front surfaces, and the figure given is simply the difference between the two opposing actions. Experiments show that this explanation is correct.

Besides water, other screens are used to filter the radiation of the candle before it falls on the disks. Water is, however, preferred for several reasons. It is almost perfectly opaque to the invisible heat rays, and, therefore, its employment allows easy discrimination between actions due to heat and to heat and light combined; secondly, it is colourless, and having no selective action on any visible ray of light, it can be used in conjunction with any coloured powder without complicating the results. Alum acts in a similar manner to water; coloured solutions act as water with a superadded action due to their colour. Very thick plates of glass have less action on the invisible heat rays than a thin layer of water. Sulphate of copper in so weak a solution as to appear only slightly green, has a very strong action when artificial light is used, as it cuts off the lowest visible red rays as well as the ultra red.

After having given the tabulated results of the examination and discussed the different actions, the author finds that the substances experimented on may be divided into two classes.

1. In which the repulsion behind water is *greater* in proportion to the standard than when no screen is present; and 2, in which the repulsion in proportion to the standard is *less* behind water than when no screen is present. Amongst class 1 may be mentioned copper

tungstate, saffranin, scarlet selenium, and copper oxalate; these are more affected by light than by invisible heat. Amongst class 2 may be mentioned pale green chromic oxide, persulphocyanogen, hydrated zinc oxide, barium sulphate, and calcium carbonate; these substances are more acted on by the ultra red rays than by the luminous rays.

From the results given in these tables, the author has been led to the construction of several radiometers which afford ocular proof of the general correctness of the indications given by the water screen. Thus, a radiometer made of pith disks coated on alternate sides with chromic oxide and precipitated selenium, moves in one direction to the naked flame of a candle and in the other direction when a water screen is interposed. A similar radiometer coated with saffranin and hydrated zinc oxide does not move at all when exposed to the naked flame, but revolves when a water screen is interposed. A radiometer coated with thallic oxide and Magnus's green platinum salt moves strongly when no screen is interposed, but is stopped by a water screen. Many other instruments having similar behaviour to the above are described, and their actions discussed and explained. The following experiment is given; a pith radiometer, coated with precipitated selenium and chromic oxide, is exposed to the radiation from a colourless gas flame from a Bunsen burner, coloured intensely green by thallium. To the eye, by this light, the chromic oxide looks nearly white and the scarlet selenium black. The rotation due to the superior repulsion of the chromic oxide is, however, apparently as strong as when the non-luminous flame is used. This is a proof that the train of reasoning the author has employed on former occasions is correct, viz., that certain substances have an absorptive action on rays of dark heat opposite to what they have on light, and that an optically white body may be thermically black, and *vice versâ*. Here, for instance, chromic oxide is optically green and thermically black, whilst scarlet selenium is thermically white.

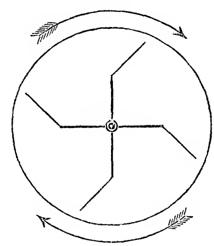
The author next examines the amount of repulsion produced when polarised light is allowed to fall on a plate of tourmaline suspended in vacuo in a torsion balance. It was considered possible that the repulsion might vary according to the plane of polarisation of the incident ray. Three separate sets of experiments are given in detail, and the results discussed; the final decision being that the special action originally thought possible does not exist in a degree appreciable with the present experimental means.

The next portion of the paper is devoted to an examination of the action of radiation on radiometers, the vanes of which consist of metallic plates, either bright on both sides or blacked on one side, and turned up at the corners in different degrees. When flat plates are taken, blacked on alternate sides, the rotation is normal or positive,

i.e. the black side is repelled. If one of the outer corners of each plate is turned up at an angle of 45°, so as to keep the blacked surface on the concave side, the positive rotation is either diminished, stopped, or converted into negative rotation, according to the amount of surface of the plate which has been turned up.

When the plates are kept flat, but the supporting arms are bent so as to present more of one side than of the other to the bulb, as shown in fig. 1, the fly rotates under the influence of radiation in the direction

Fig. 1.



of the arrows, even when there is no difference between one surface and the other. It is shown that the favourable presentation of the surface of the vanes to the inside of the bulb has more influence on the movement than has the colour of the surface. Experiments are described with radiometers of the form shown in fig. 1, and made of thick and thin mica, pith, aluminium bright on both sides, and aluminium blacked on one side. The action of light and of dark heat is given. The negative rotation set up in the fly when it is cooling from a high temperature, and the anomalous behaviour of the "favourably presented" radiometers when immersed in hot air or hot water, are examined. It is found that when a hot metal ring is applied to the equator of the bulb, the direction of rotation is always positive; and that when a hot ring of a smaller diameter is applied to the top or bottom of the bulb the direction of rotation is always negative. The direction of movement when the hot rings are removed and the fly is cooling is positive with the aluminium vanes, and negative with the thin mica and pith vanes.

The positive rotation, when the bulb is heated equatorially, is independent of the material of which the fly is made. It is caused by the hot ring of glass generating molecular pressure, which radiates towards the centre, and strikes the sloping vanes, driving them round as if a wind were blowing on them. The other movements of these "favourably presented" radiometers are explained in the paper, but it is difficult to reproduce the explanations in abstract without the aid of the diagrams which accompany the paper.

Having investigated the simplest form of favourably presented

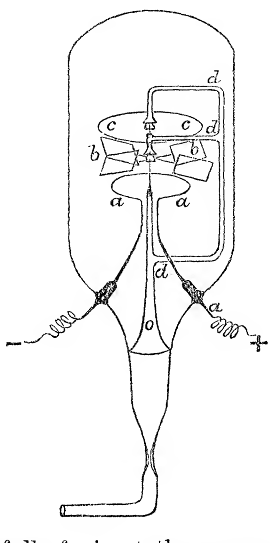
vanes, the author describes experiments with metal and other cones, cylinders, and cups. An abstract of some of these results was given in the Proceedings of the Royal Society for November 16, 1876, No. 175, page 313, but it was stated that the "molecular pressure" theory seemed incapable of accounting for some of the movements there observed. Further experiments have now cleared up this difficulty, and all the various movements are now seen to agree with this theory. The movement which appeared most anomalous was the attraction observed when a candle was allowed to shine on the hollow side of a cone or cup-vaned radiometer, the light being screened off the retreating side. When light falls on the hollow side of a cone-shaped vane, some is reflected and lost, but some is absorbed and is converted into heat of temperature. Aluminium being a good conductor of heat, and the thickness of metal being insignificant, it becomes equally warm throughout, and a layer of molecular pressure is formed on each surface of the metal. At a low exhaustion the thickness of this layer of pressure is not sufficient to reach from the metal cone to the side of the glass bulb. As the exhaustion increases, this layer extends further from the generating surface, until at a sufficiently high exhaustion the space between the side of the glass bulb and the adjacent portion of the metallic cone is bridged over, and pressure is exerted between the two surfaces. The more favourable presentation offered by the cone causes the pressure to be greatest between the glass bulb and the outside of the cone; the vanes are, therefore, pressed round by a force which is really acting from behind, although the movement looks as if the candle were attracting them.

A radiometer, the fly of which is furnished with four bright aluminium cups, rotates in the light as well as a flat vaned instrument blacked on one side. Experiments are described with one of these instruments attached to the mercury pump, and the observations of pressure and revolutions per minute under the influence of a standard candle are tabulated and drawn as a curve, taking the rarefaction of the air in millionths of an atmosphere as abscissæ and the number of revolutions a minute as ordinates. The curve, which is traced through the dots representing observations, shows a gradual increase in the sensitiveness of the instrument to light, up to about 50 millionths of an atmosphere; then the action keeps with little variation to about 30 millionths, thence it rapidly sinks, until at about 1 millionth it is less than $\frac{1}{38}$th of the maximum, and at 0·2 millionth the radiometer refuses to turn even when five candles are put near it.

The concluding portion of the paper is devoted to an examination of the movements produced in highly rarefied gases, when thin mica vanes suspended horizontally, and sloping like the vanes of a windmill, are exposed to the action of a ring of platinum, placed just below them, and rendered incandescent by a current of electricity. The

object has been to produce the molecular pressure by a very intense heat which would not have to pass through glass, and to allow it to act on vanes which are turned in the most favourable position for rotating under the influence of the molecular pressure. The direction is called *positive* when it is the same as would be produced by a wind blowing from the platinum wire, and *negative* when it takes the contrary direction. In the apparatus most experimented with a rotating disk of mica is supported on a separate pivot, immediately over the mica vanes. The normal or positive movement of this disk is in the opposite direction to that of the vanes; thus, if the positive movement of the vanes is in the direction of the hands of a watch, the positive movement of the disk is in the opposite direction.

FIG. 2.



With the apparatus full of air at the normal pressure the direction of rotation, both of the vanes and disk, is *positive* when the platinum wire is ignited. This is probably due to the ascending current of hot air.

At a pressure of 80 millims. the disk does not rotate. The vanes rotate *positively*, but slowly.

At 19 millims. no movement whatever takes place. The disk and vanes are as still when the wire is heated as when it is cold.

At 14 millims. the disk remains stationary. The vanes move slowly in the *negative* direction.

At 1 millim. the disk rotates in the *positive* direction slowly, whilst the vanes rotate *negatively* rather fast; both disk and vanes now rotate in the same direction.

At a pressure of 706 millionths of an atmosphere the direction keeps the same as at 1 millim. in each case, but the speed is greater.

At 294 millionths, the speed of the disk and vanes is exactly alike, both rotating together in the same direction. Up to this pressure and at some distance beyond, the vanes have been gradually diminishing whilst the disk has been increasing in speed. At a pressure of 141 millionths the disk rotates rapidly, *positively*, but the vanes do not rotate at all. At a little higher exhaustion than the last, viz., at 129 millionths, a great change is observed. The vanes, which were still, now rotate in the *positive* direction at a speed of 100 revolutions a minute, whilst the disk rotates positively as before, but with a little diminished velocity. It is probable that some of the speed of the disk has been quenched by the rapid movement of the vanes in the opposite direction, as the author has previously shown* that the viscosity of air at a rarefaction of 129 millionths of an atmosphere is only a little less than its viscosity at the normal density, and hence the vanes, at a speed of 100 revolutions a minute, must exert a considerable drag on the opposite rotation of the disk.

As the rarefaction increases above this point, the speed of both the disk and vanes increases, till they exceed 600 revolutions a minute. At the highest rarefaction attained (0·4 millionth of an atmosphere), there is no apparent diminution in speed.

These experiments have been repeated in a more elaborate series with an apparatus of great complexity. It is impossible without drawings to give an idea of the various arrangements by which data are secured, but it may be mentioned that at each pressure observations can be taken on the velocity of rotation of the disk and vanes, the viscosity of the residual gas, the repulsion exerted by a standard candle on a black mica plate, and the appearance of an inductive spark through a tube furnished with platinum wires. Different gases can be experimented with, and a series of observations are given with hydrogen gas as well as with air.

The author concludes his paper by showing that the ordinary ideas of a "vacuum" are very erroneous. Formerly an air-pump which would diminish the volume of air in the receiver 1,000 times was said to produce a vacuum. Later a "perfect vacuum" was said to be produced by chemical absorption and by the Sprengel pump, the test being that electricity would not pass; this point being reached when the air is rarefied 100,000 times. According to Mr. Johnstone Stoney, the number of molecules in a cubic centimetre of air at the ordinary pressure is probably something like 1,000,000000,000000,000000 (one thousand trillions). Now when this number is divided by 0·4 million, there are still left 250,000000,000000 molecules in every cubic centi-

* "Proceedings of the Royal Society," November 16, 1876, No. 175, p. 305.

metre of gas at the highest exhaustion to which these experiments have been carried. Two hundred and fifty billions of molecules in a cubic centimetre appear a sufficiently large number to justify the supposition that when set into vibration by a white-hot wire they may be capable of exerting an enormous mechanical effect.

January 24, 1878.

Sir JOSEPH HOOKER, K.C.S.I., in the Chair.

The presents received were laid on the table, and thanks ordered for them.

The following papers were read:—

I. "New Determination of the Mechanical Equivalent of Heat." By J. P. Joule, LL.D., F.R.S. Received November 15, 1877.

(Abstract.)

An account is given by the author, of the experiments he has recently made, with a view to increase the accuracy of the results given in his former paper, published in the "Philosophical Transactions" for 1850. The result he has now arrived at, from the thermal effects of the friction of water, is, that taking the unit of heat as that which can raise a pound of water, weighed in vacuo, from 60° to 61° of the mercurial thermometer; its mechanical equivalent, reduced to the sea-level at the latitude of Greenwich, is 772·55 foot-pounds.

II. "The Cortical Lamination of the Motor Area of the Brain." By Bevan Lewis, F.R.M.S., Pathologist and Assist. Med. Officer to the West Riding Asylum, and Henry Clarke, L.R.C.P. Lond., Med. Officer to the West Riding Prison. Communicated by D. Ferrier, M.A., M.D., F.R.S., Professor of Forensic Medicine, King's College, London. Received November 7, 1877.

[Plates 1–3.]

Whilst pursuing certain investigations upon the comparative histology of the brain, the authors of this article have been enabled to demonstrate certain facts with regard to cortical lamination, and to show the disposition and significance of certain elementary constituents, the importance of which, they believe, justifies their publication.